1885028

Hydrologic & Geochemical Investigation of Illinois Gulch/Iron Springs, Breckenridge, CO

Rob Runkel (runkel@usgs.gov) & many others...
USGS Colorado Water Science Center / Toxic Substances Hydrology Program

Preliminary Results as of April 12, 2017

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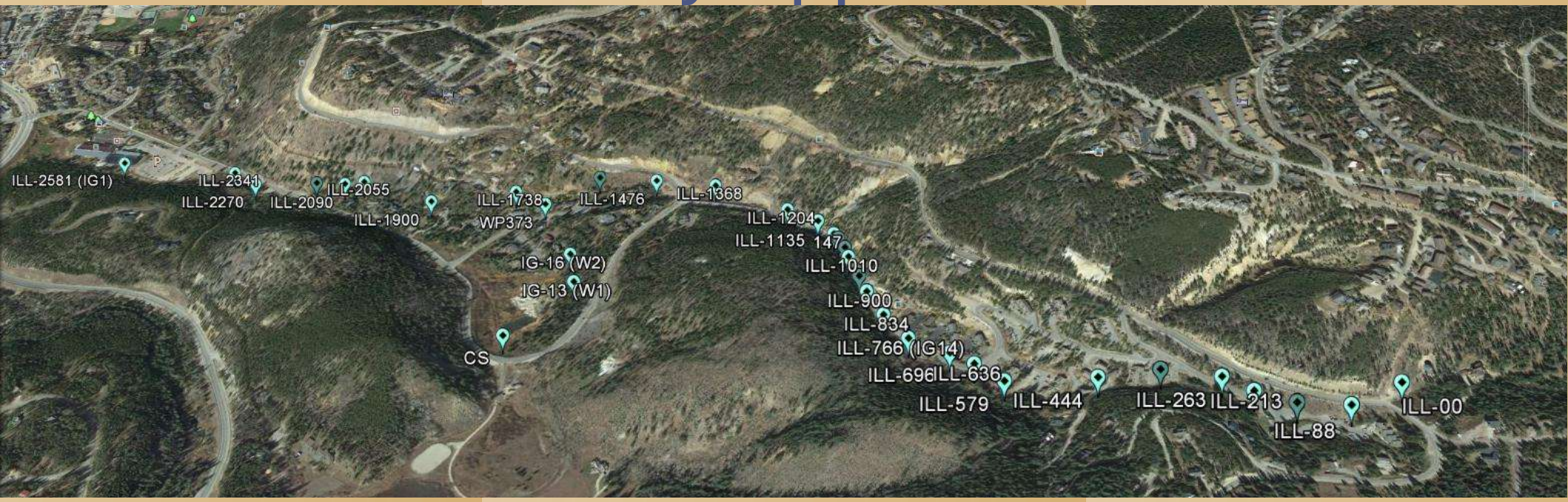
Overview: August 2016 Study

- Study Approach / Watershed Tour
- Hydrology:
  - Stream Gaging
  - Continuous Injection of NaBr (Tracer-dilution)
  - Slug Injections
- Water Quality / Geochemistry
  - Concentrations/Standards
  - Loading profiles and sources
  - Loads associated with flow loss near Puzzle Extension Shaft

Study Approach



- Goals: Quantify Hydrology (primary) & Water Quality
- Approach: Subdivide reach into segments & Sample at end of each segment
- Spatial snapshot: Streamflow (tracer-dilution), Conc. (synoptic sampling), Load
- Illinois Gulch:
  - 2.5 km Study Reach
  - Segment Length: 50-200 m
  - 31 stream sites, 7 inflows, 5 off stream inflows, + Iron Springs/Little Mt

Site Tour – Upstream to Downstream

ILL-0000

ILL-0353

ILL-1074

~ILL-1090

Site Tour – Upstream to Downstream

ILL-1204

ILL-1368

ILL-1383

ILL-1476

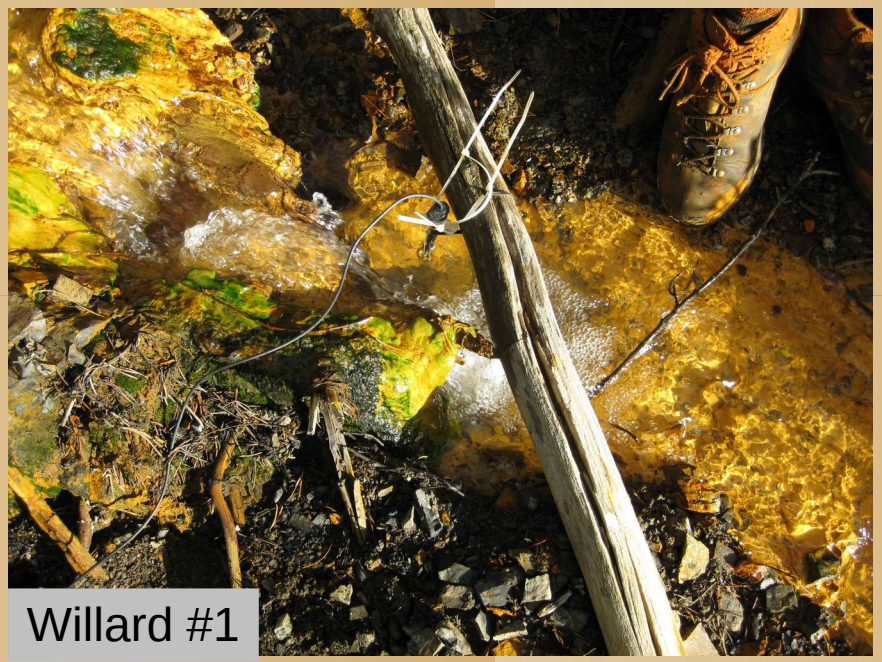
Site Tour – Upstream to Downstream

~ILL-1900

ILL-2126, Iron Springs at Mouth

ILL-2581 / IG-01

Site Tour – Off Stream Inflows – Where's the Bromide?

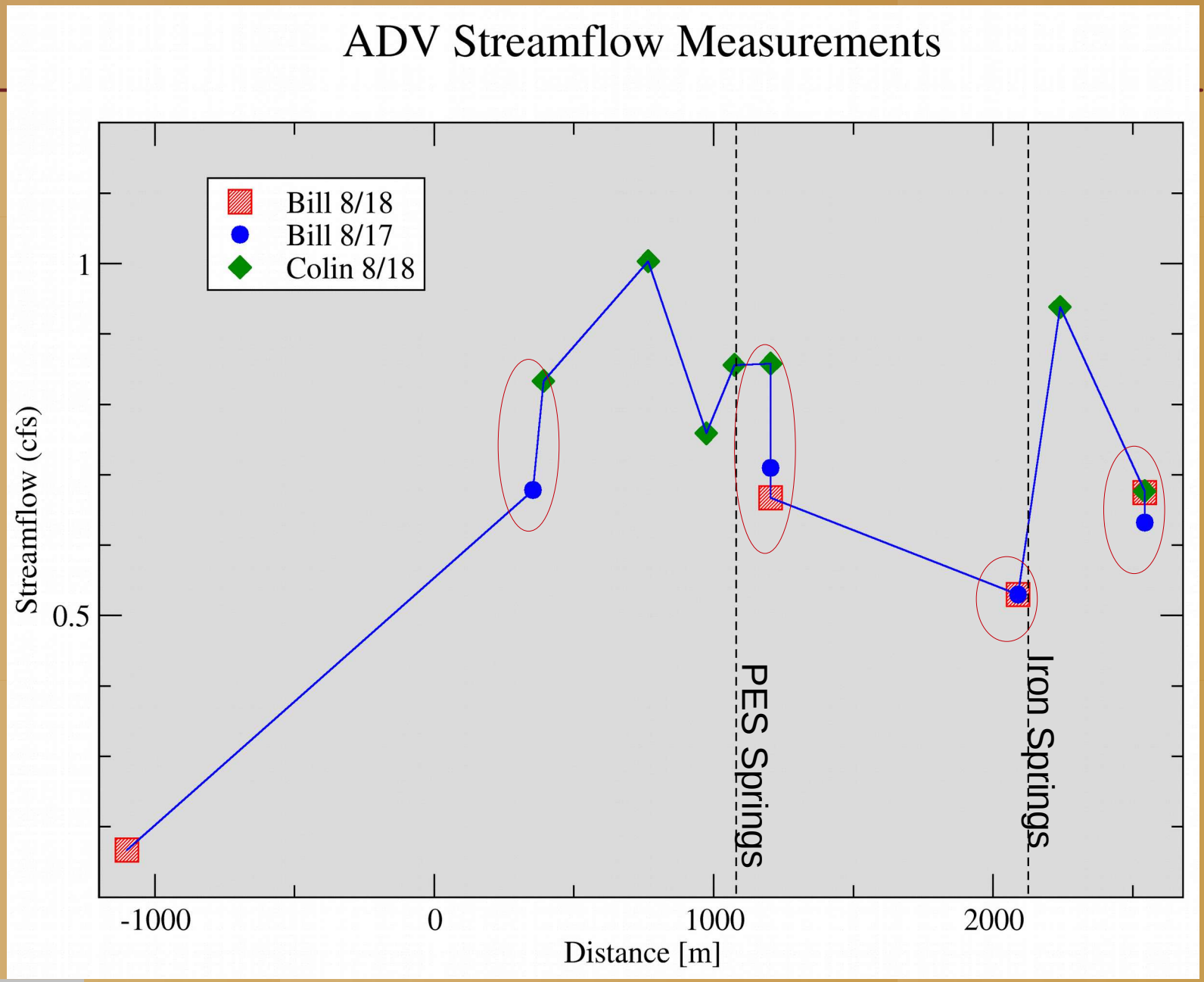

Willard #1


Willard #2


Robber's Nest


WP373

Hydrology – Streamflow by ADV



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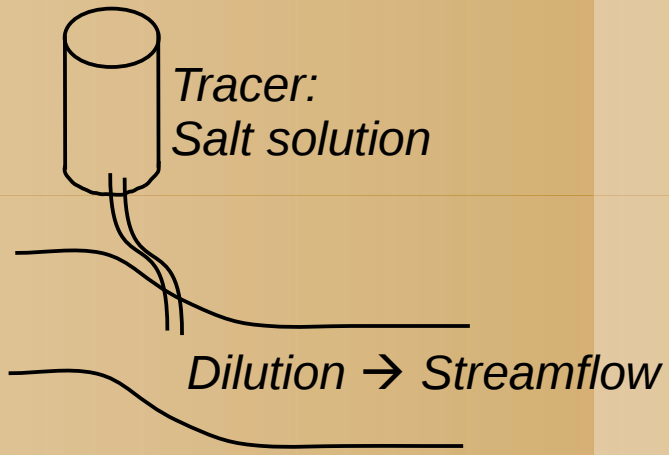
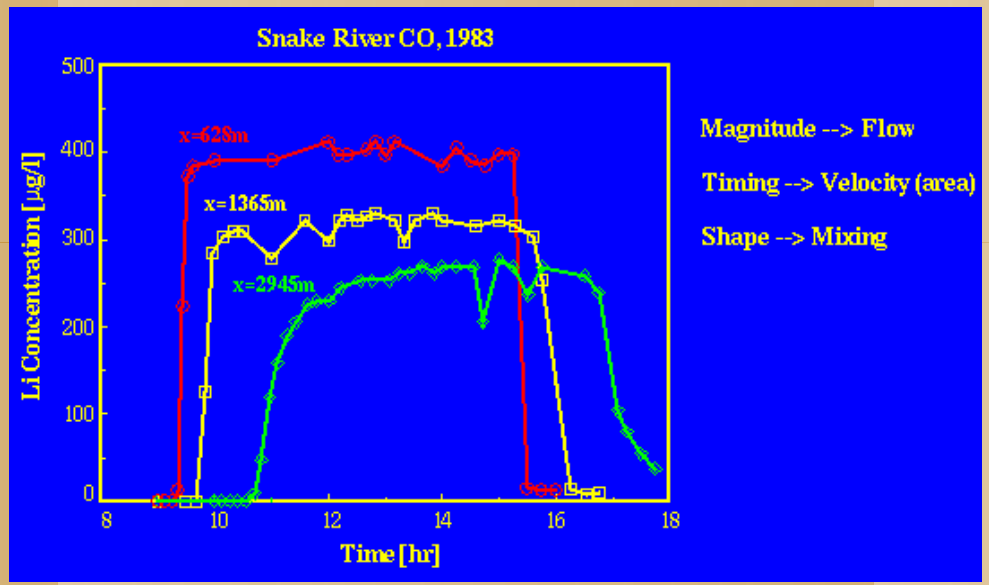
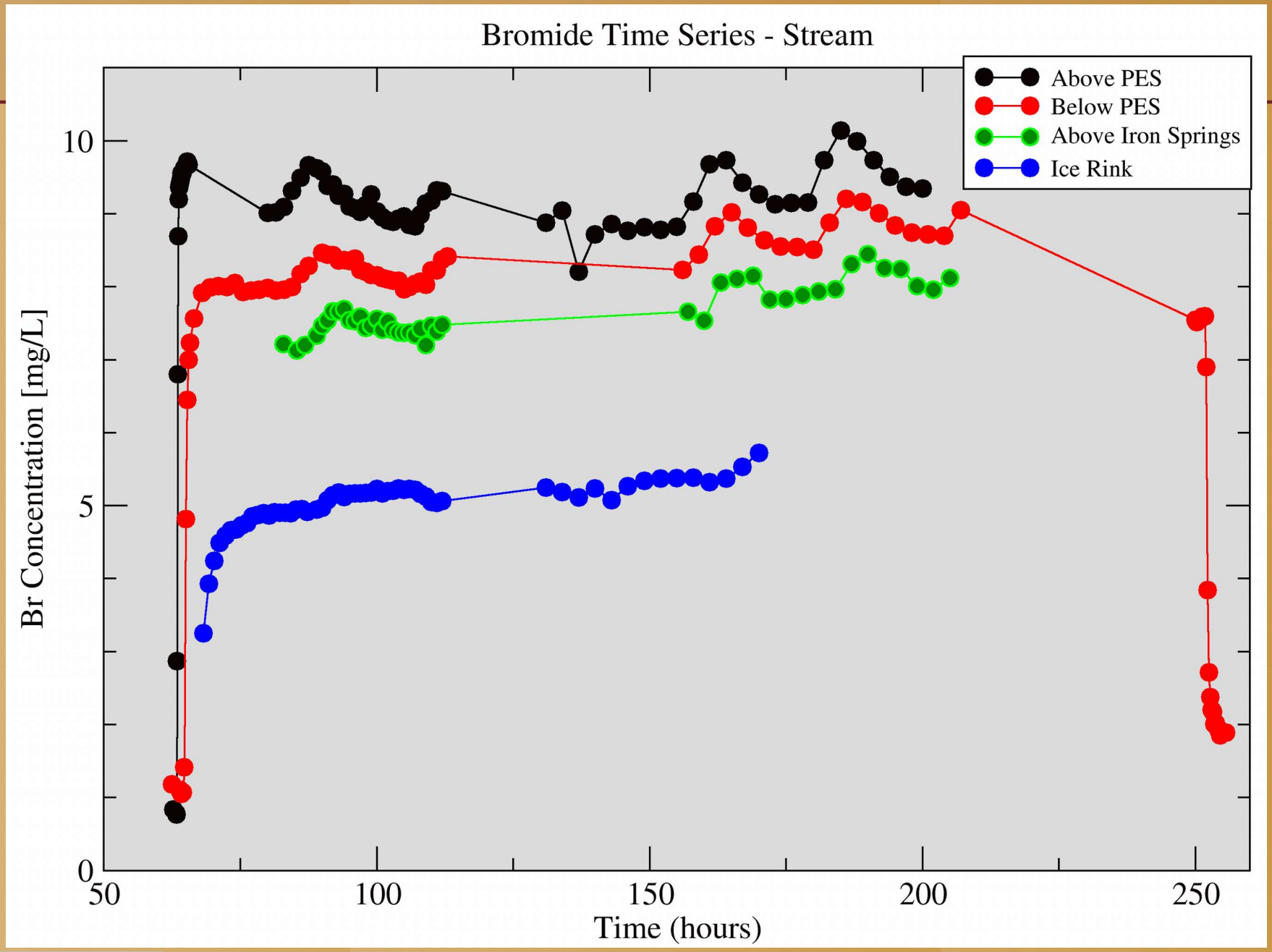
The Tracer-Dilution Method





Downstream Dilution



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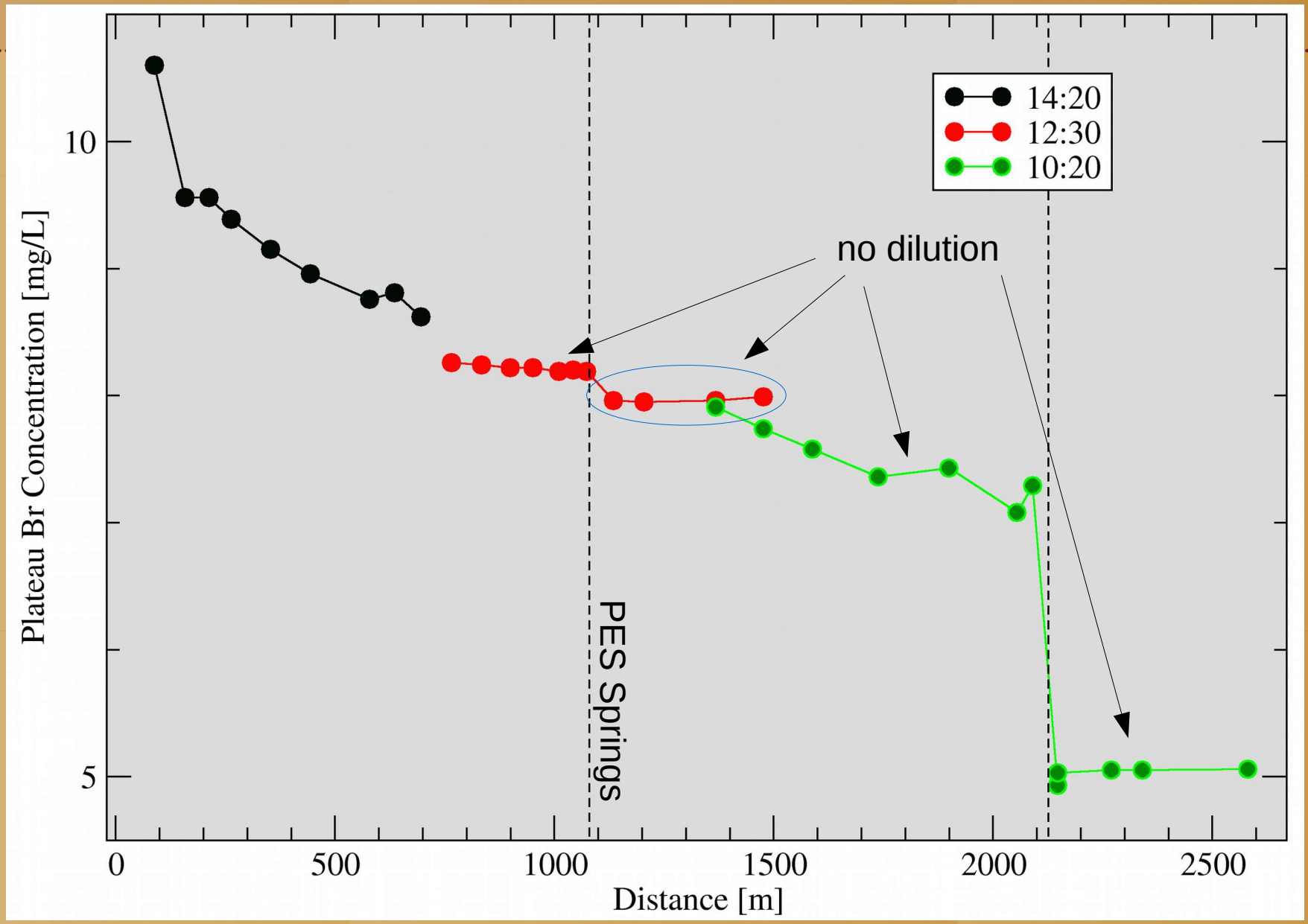
Dilution (or lack thereof) w/ Distance

(what happens when we lose water?)



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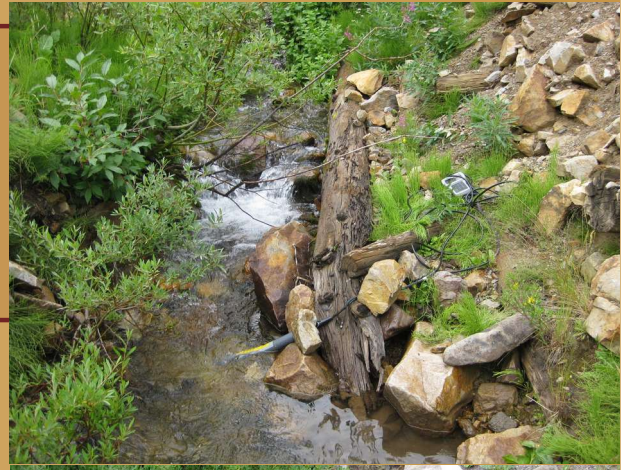
Slug Injections



Absolute Q:

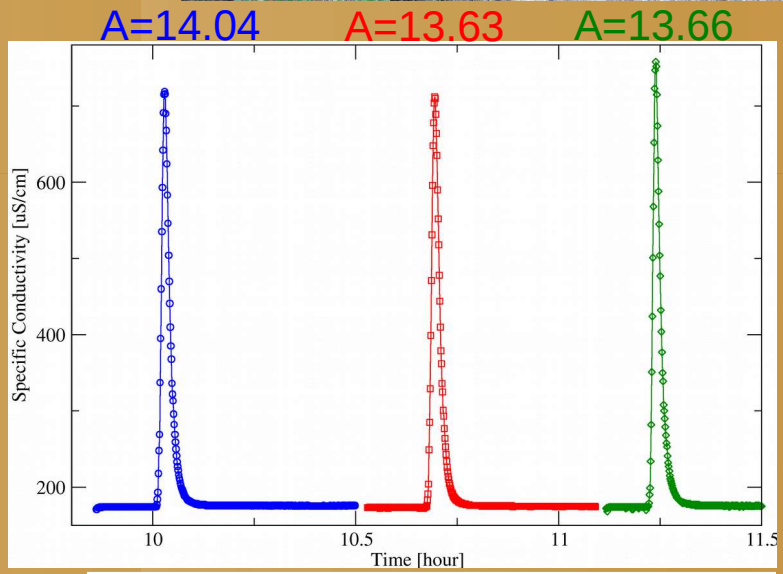
Q = mass salt / area under curve = M / A

Relative Q:

$Q_u = M/A_u$ & $Q_d = M/A_d \rightarrow Q_d/Q_u = A_u / A_d$

Approach:

- known mass of MgCl
- relative Q
- conductivity as surrogate for concentration



Q_d/Q_u = 13.66/14.04 = 0.97

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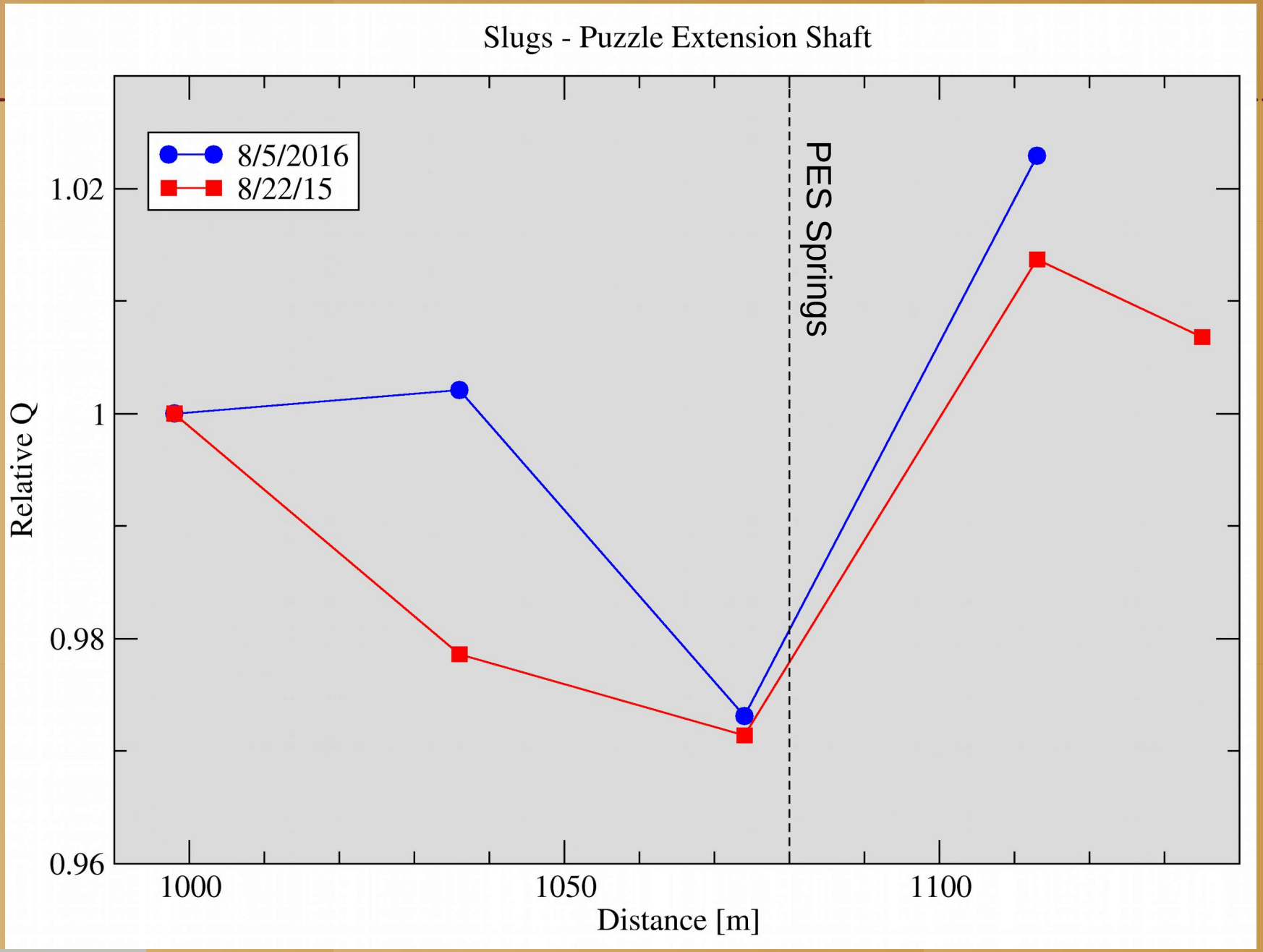
Slug Injections



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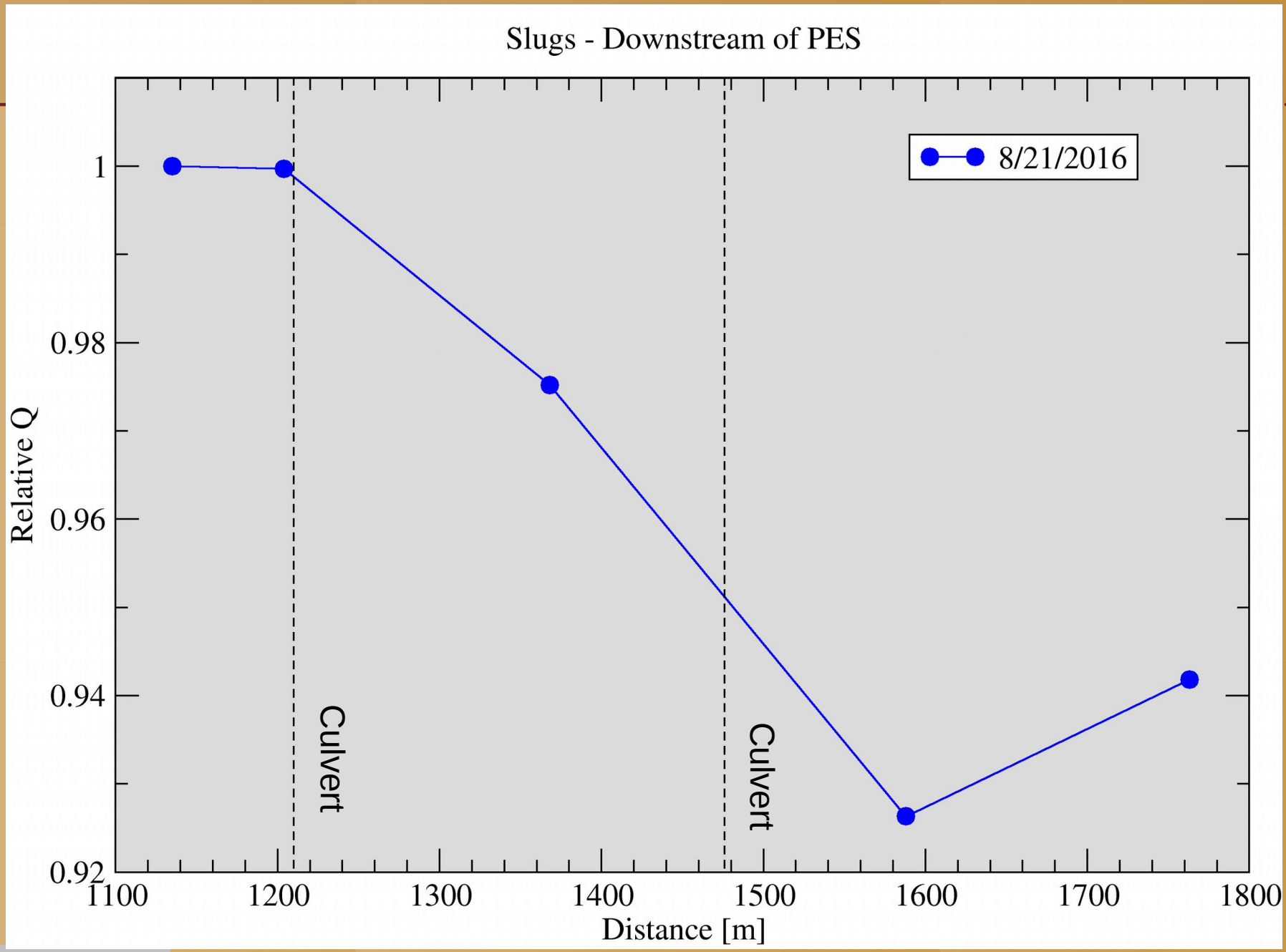
Slug Injections



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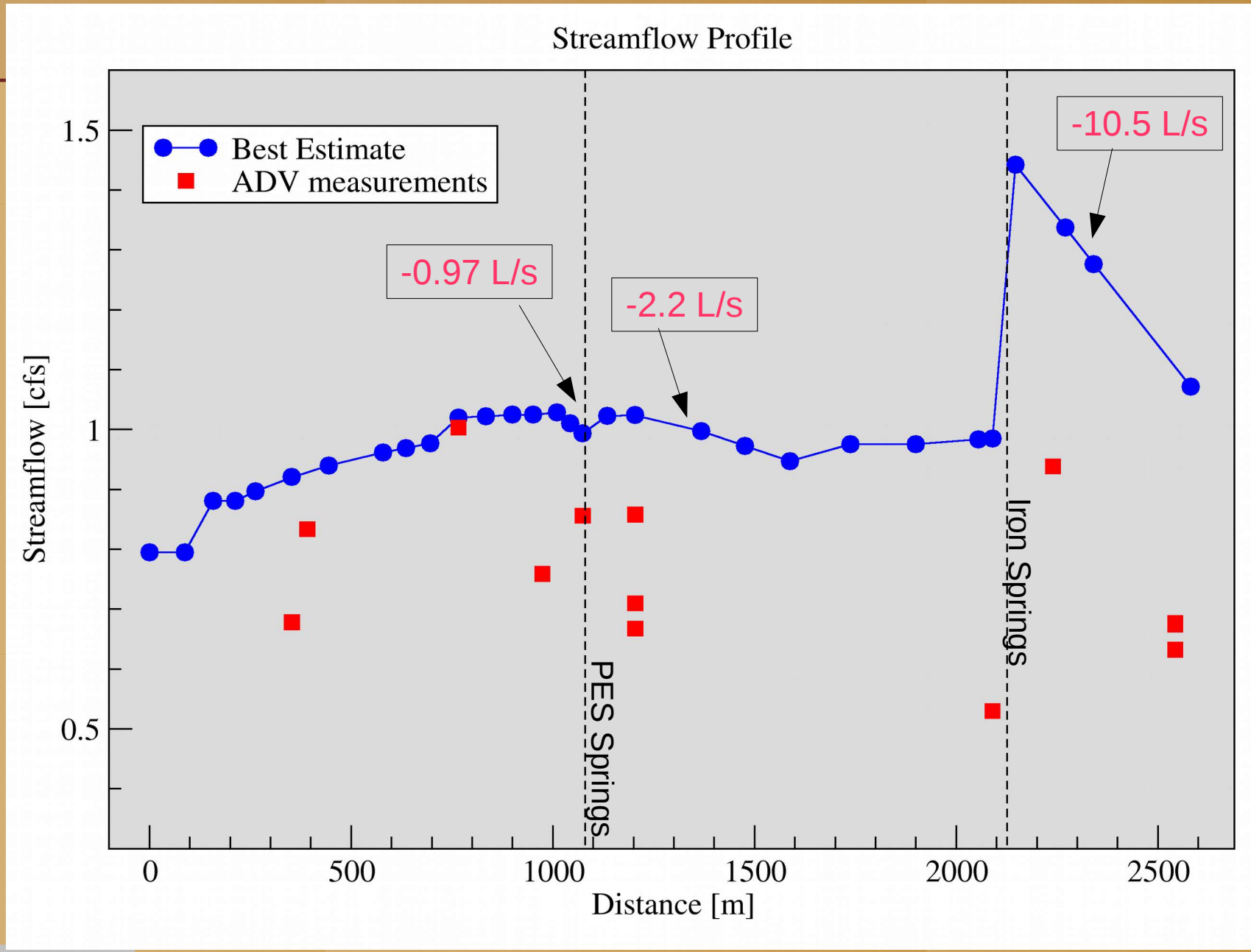
Flow Profile:
Combining Continuous Injection & Slug Info & ADV



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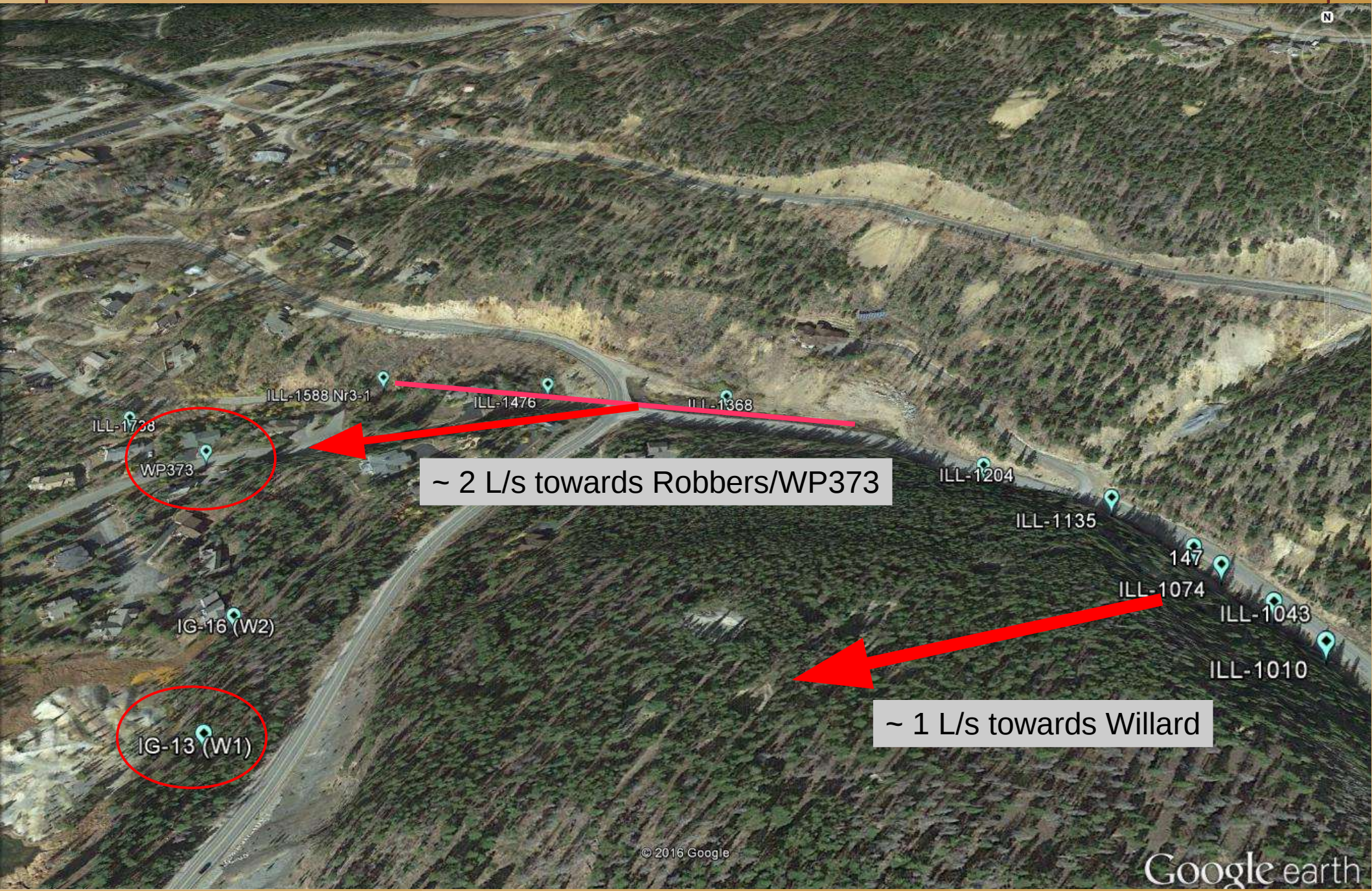
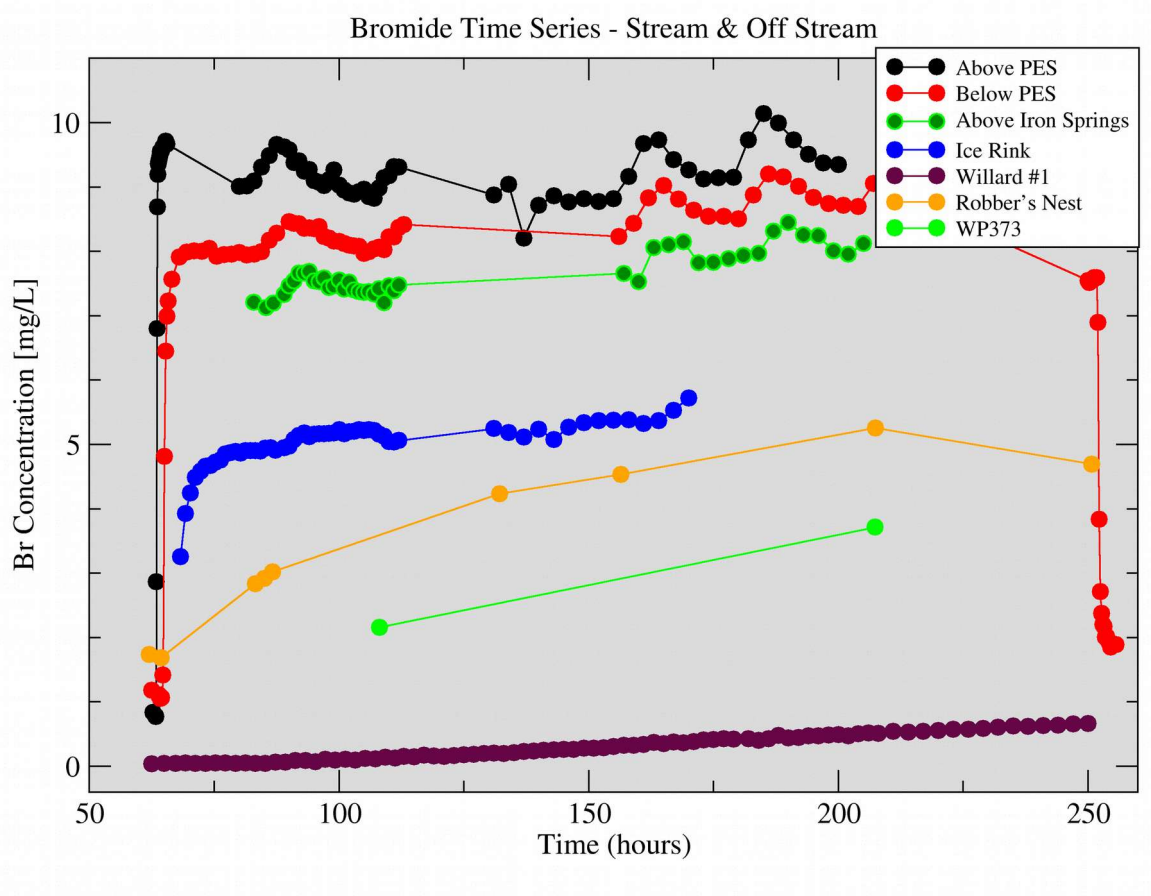
Flow Profile: Areas of Flow Loss



Br detected Off Stream



Br Conc. of Water Leaving Stream: ~8

Robber's Nest Inflow, plateau ~5

5/8 = 0.625 → 63% of RN water comes from Stream

WP373, max ~3.7

3.7/8.0 = 0.46 → **At least** 46% from stream

Willard 1, max 0.665

0.665/8.0 = 0.08 → At least 8% from stream, likely much more.

Willard Flow 8/17-18: 1.8 L/s
Loss by PES: 1 L/s

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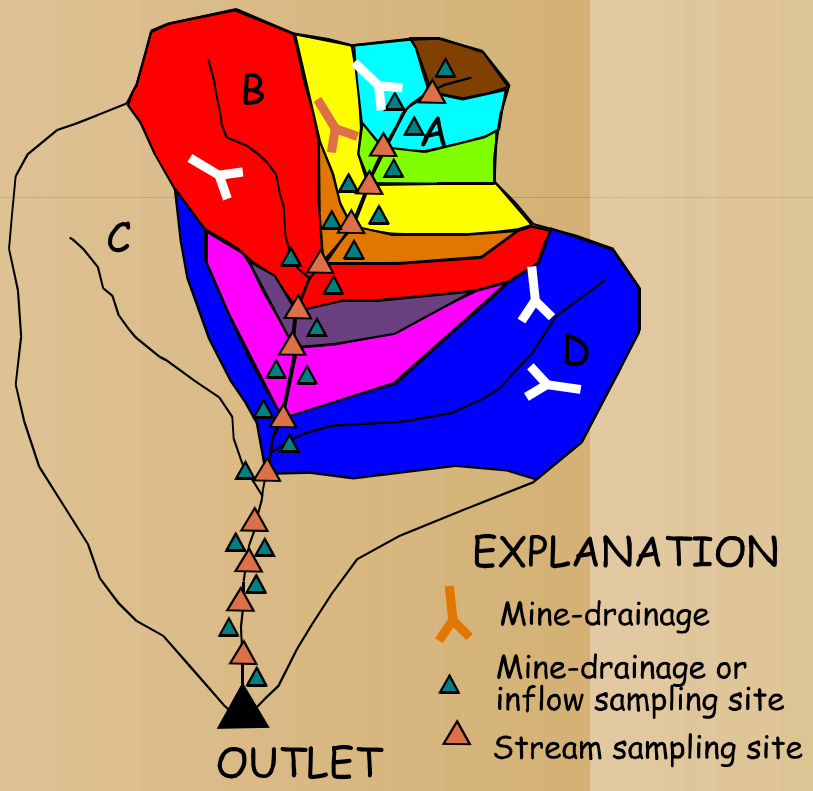
Synoptic sampling → Source Characterization



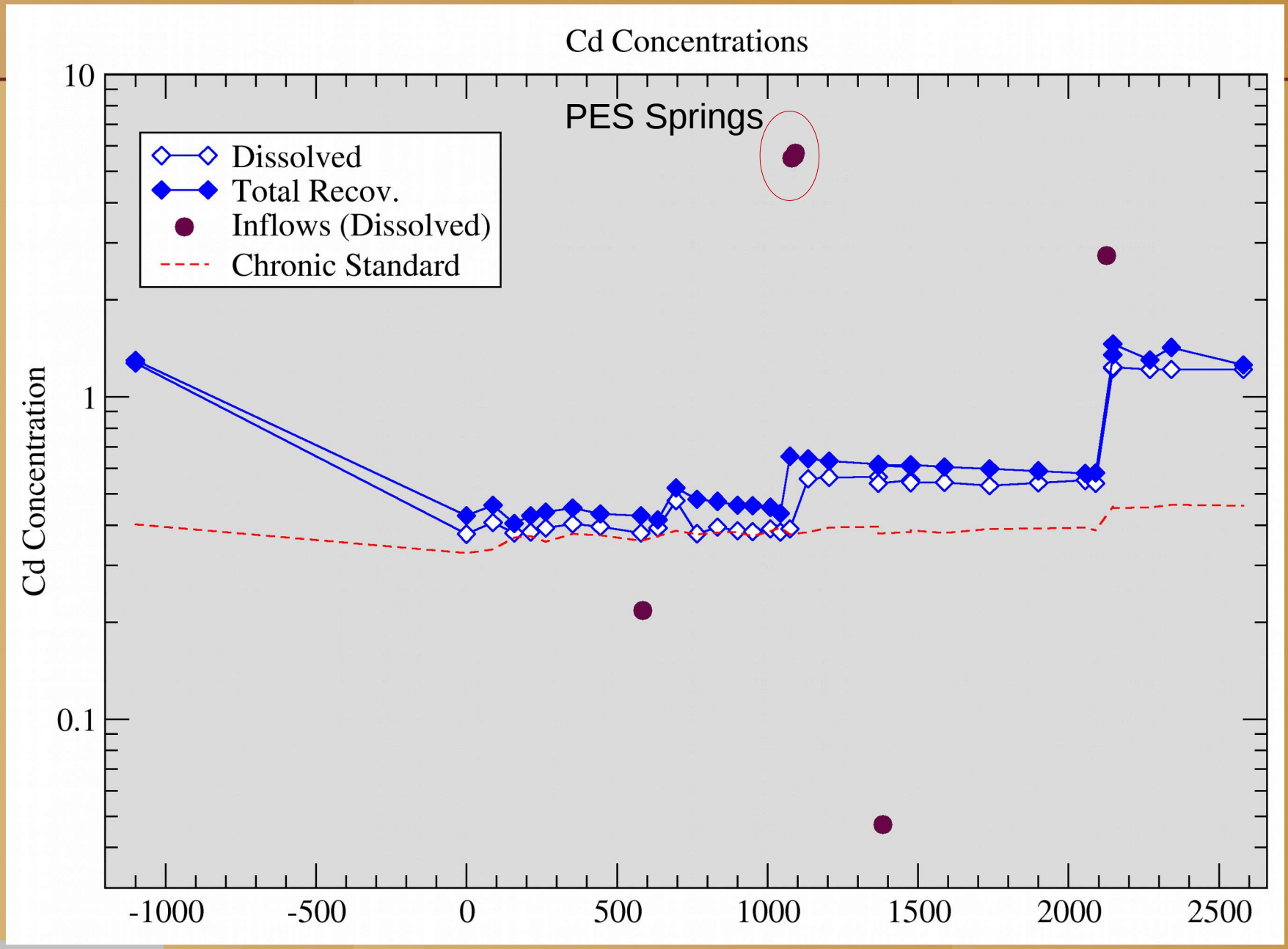
- Many Sources, Few $$
- Prioritize Sites, Evaluate options
- Estimate Loads:

Streamflow
x
Concentration
→ *Load* = mass/time

Illinois Gulch:

- 2.5 km Study Reach
- Segment Length: 50-200 m
- 31 stream sites, 7 inflows, 5 off stream inflows, + Iron Springs/Little Mt

Water Quality – Cd Concentration



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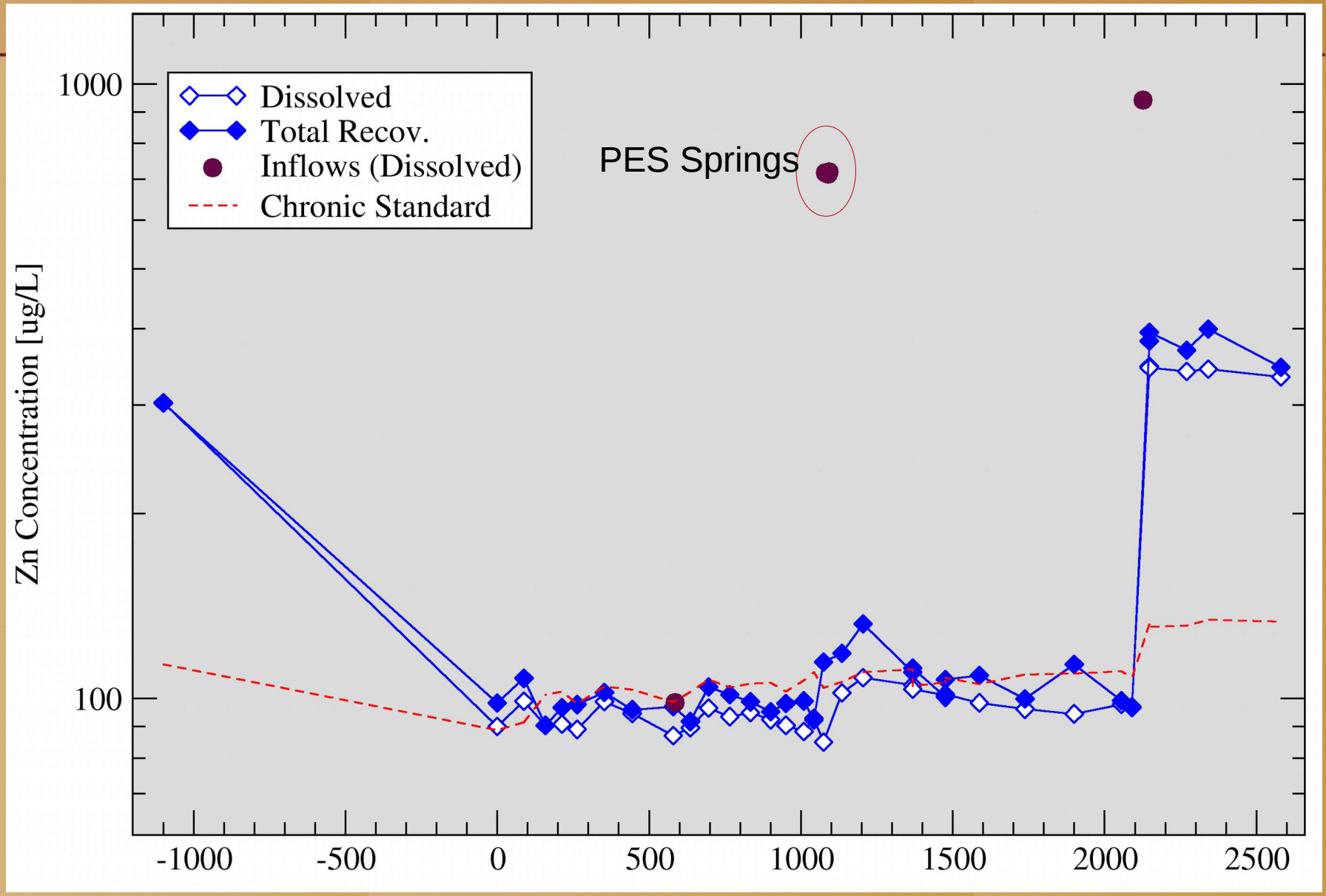
Water Quality – Zn Concentration



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Water Quality – Chronic Standard

- Cd – exceeds standard for entire study reach
- Zn – exceeds standard downstream of Iron Springs
- Meets Chronic Standard:
  Ag, Al, As, Cr, Cu, Fe, Mn, Ni, Pb, U

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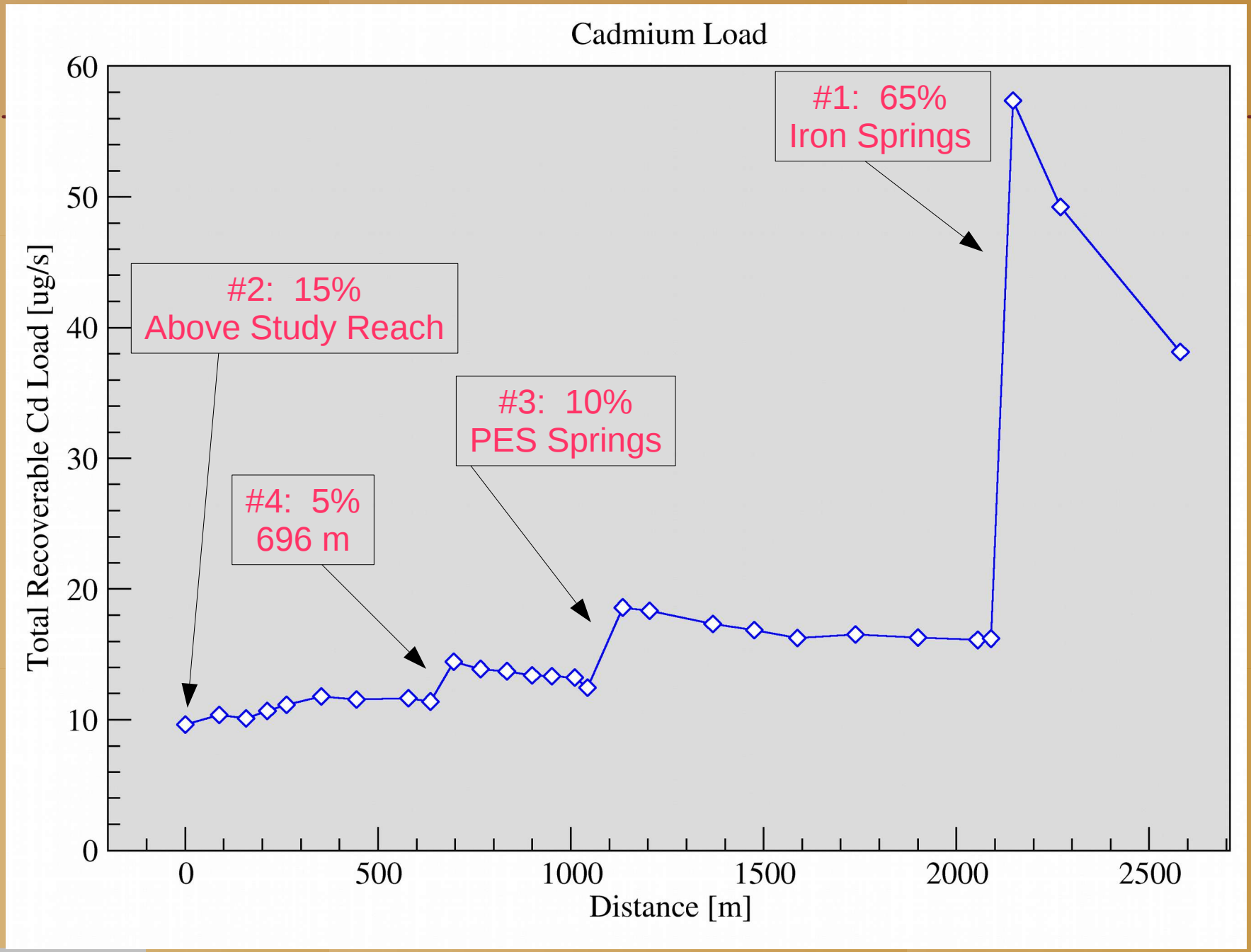
Water Quality – Loads & Sources



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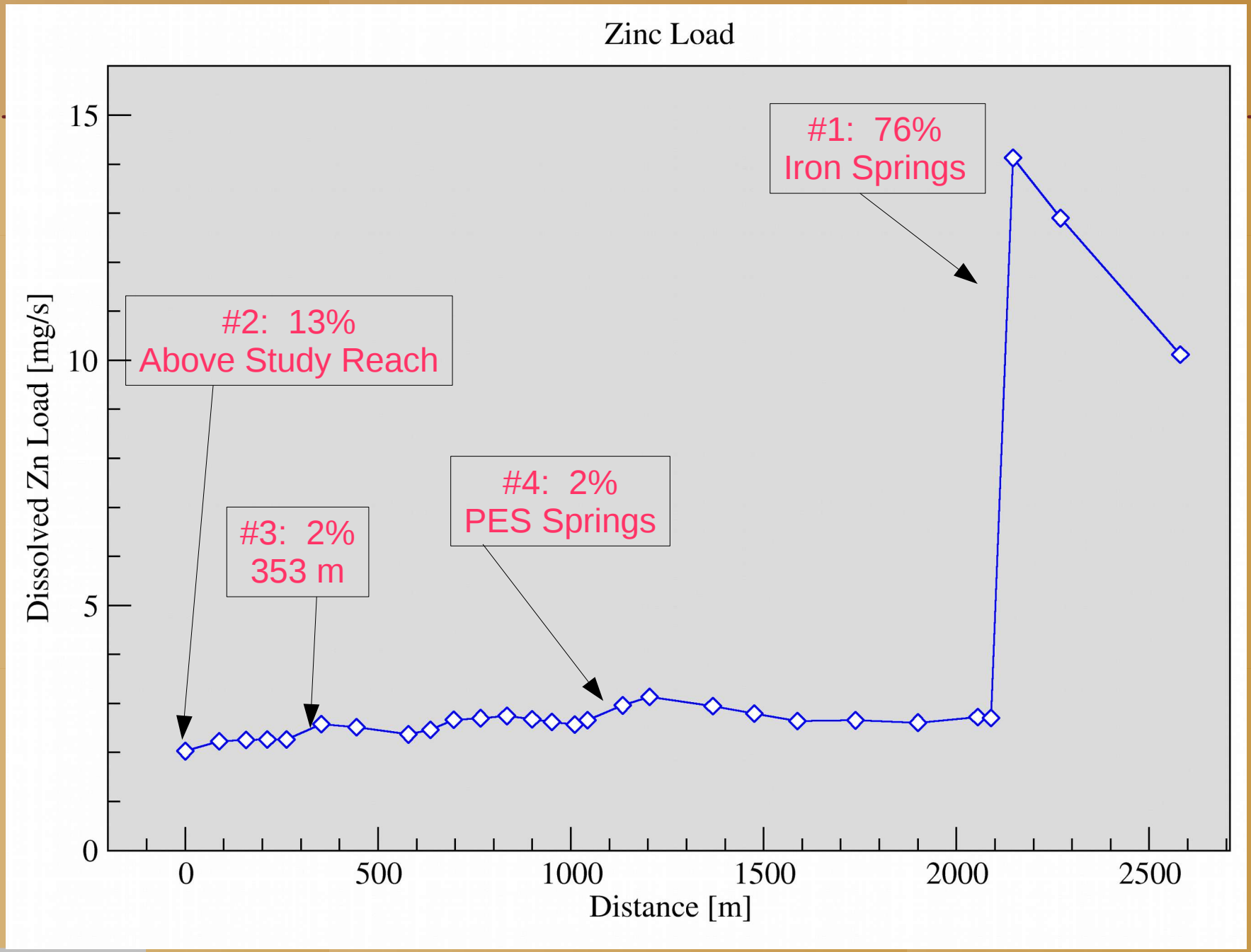
Water Quality – Loads & Sources



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Source #1: Iron Springs Gulch at Mouth

- #1 Source: Al, Cd, Cu, Fe, Mn, Ni, Pb, U, Zn
- #2 Source: As, Cr

Rank	Constituent	Contribution
1	Al	42%
1	Cd	65%
1	Cu	45%
1	Fe	67%
1	Mn	89%
1	Ni	78%
1	Pb	31%
1	U	36%
1	Zn	76%
2	As	29%
2	Cr	13%

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Source #2: Above Study Reach

- #1 Source: As, Cr
- #2 Source: Cd, Fe, Ni, U, Zn

Rank	Constituent	Contribution
1	As	33%
1	Cr	28%
2	Cd	15%
2	Fe	9%
2	Ni	8%
2	U	36%
2	Zn	13%
3	Al	14%
3	Mn	3%
3	Pb	11%
4	Cu	10%

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Source #3: Springs at Puzzle Extension Shaft

- #2 Source: Pb
- #3 Source: Cd

Rank	Constituent	Contribution
2	Pb	22%
3	Cd	10%
4	As	5%
4	Zn	2%
5	U	3%
6	Al	4%
7	Fe	2%
8	Cu	3%

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Source #1: Iron Springs Gulch

Loading from Iron Springs to Illinois Gulch
as measured at the mouth of Iron Springs:

Rank	Constituent	Contribution
1	Cd	65%
1	Zn	76%

How much of this load can be attributed to flow loss from Illinois Gulch? (Does it pay to reduce/eliminate the flow loss?)

Assumptions:

- 100% of the flow loss near the PES (~1 L/s) enters Willard 1
- 0% of the flow loss downstream of PES (~2 L/s) enters Willard 1
- unknown Iron Springs sources have water quality similar to WP373

Source #1: Iron Springs Gulch

Rank	Constituent	Contribution
1	Cd	65%
1	Zn	76%

How much of this load can be attributed to flow loss from Illinois Gulch?

Iron Springs Sources			
		Dissolved Concentration	
	Flow (L/s)	Cd (ug/L)	Zn (mg/L)
IG-13 (W1)	1.7 (flume)	32.2	8.0
IG-16 (W2)	1.5 (flume)	3.6	2.9
IG-06 (L. Mt	7.2 (flume)	0.7	0.7
IG-11 (seep)	0.3 (2012, URS)	35.5	8.9
WP373	2.2 (difference)	3.0	0.3
Cally Spring	negligible	0.05	0.01

Source #1: Iron Springs Gulch

Rank	Constituent	Contribution
1	Cd	65%
1	Zn	76%

How much of this load can be attributed to flow loss from Illinois Gulch?

Iron Springs Sources				
	Dissolved Loads			
	Cd (ug/s)	Cd (%)	Zn (mg/s)	Zn (%)
IG-13 (W1)	56	**68%**	14	**52%**
IG-16 (W2)	6	7%	4	17%
IG-06 (L. Mt	5	6%	5	19%
IG-11 (seep)	10	12%	3	9%
WP373	7	8%	1	2%

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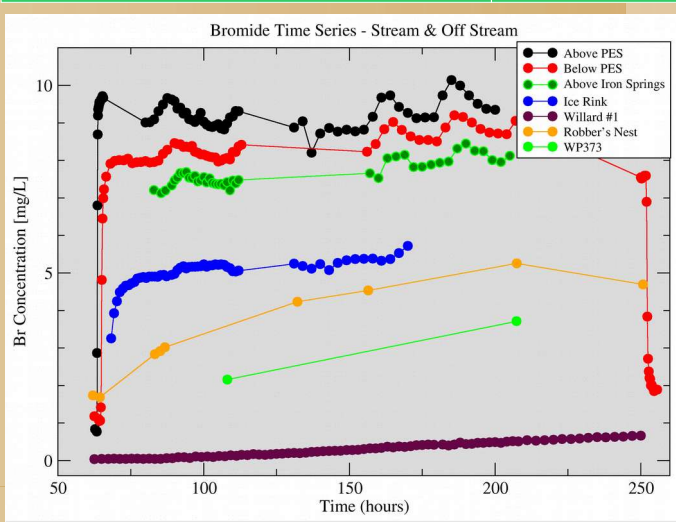
How much of this load can be attributed to flow loss from Illinois Gulch?

Iron Springs Contribution to Illinois Gulch	
Cd (%)	Zn (%)
65%	76%

IG-13 (W1) Contribution to Iron Springs	
Cd (%)	Zn (%)
68%	52%



Br Conc. of Water Leaving Stream: ~8
Willard 1, max 0.665
0.665/8.0 = 0.08 → At least 8% streamwater

Willard Flow: 1.8 L/s
Loss by PES: 1.0 L/s

Assume: all lost water comes out W1
→ 1.0 / 1.8 = **55% of W1 water is from IG**

Cd = 65% x 0.68 x 0.55 = 24%

Zn = 76% x 0.52 x 0.55 = 22%

Elimination of flow loss near PES would address <25% of the load

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OPTIONAL PESSIMISM:
How much of this load can be attributed to flow loss from Illinois Gulch?

Not all of Iron Springs load makes its way to the mouth....

Iron Springs Sources		
	Dissolved Loads	
	Cd (ug/s)	Zn (mg/s)
IG-13 (W1)	56	14
IG-16 (W2)	6	4
IG-06 (L. Mt	5	5
IG-11 (seep)	10	3
WP373	7	1
Total	84	27

Iron Springs @ Mouth				
	Dissolved Conc.		Dissolved Load	
Flow (L/s)	Cd (ug/L)	Zn (mg/L)	Cd (ug/s)	Zn (mg/s)
12.9	2.7	0.94	35	12

Only 42% (35/84) of the I. S. Cd load makes it to the mouth

Only 44% (12/27) of the I. S. Zn load makes it to the mouth

Cd = 65% x 0.68 x 0.55 x 0.42 = 10%

Zn = 76% x 0.52 x 0.55 x 0.44 = 10%

Elimination of flow loss near PES would address ~10% of the load

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Conclusions:

- Cd – exceeds chronic standard for entire study reach
- Zn – exceeds chronic standard downstream of Iron Springs
- Iron Springs Gulch is the largest source to Illinois Gulch
- Willard #1 is the largest source w/i Iron Springs
- Willard #1 is fed by streamflow loss from Illinois Gulch
- Eliminating this loss would reduce Iron Springs Loads

Additional Work to Reduce Uncertainty:

- Slug injections below the Puzzle Extension Shaft
  (to confirm losses documented by slugs on 8/21/16)
- Slug injections below the Iron Springs/Illinois Gulch Confluence
  (to confirm losses documented by ADV measurements)
- Tracer-based Synoptic of Iron Springs Area
  (to more accurately estimate loading from Willard 1 and other sources)
- Long term (~20-30 days) injection in Illinois Gulch
  (to determine % of Willard #1 that emanates from Illinois Gulch flow loss)

Notes

- Study completed under a joint funding agreement between the U.S. Geological Survey and the Colorado Department of Public Health and the Environment. Additional support provided by the USGS Toxic Substances Hydrology Program.

- Slide 1 photograph by Allen Sorenson, State of Colorado; all other photos by R.L. Runkel, USGS

- Green shading in tables used to highlight information on constituents that exceed the standard (Cd, Zn)

- Abbreviations/Nomenclature:

  Acoustic Doppler Velocimetry (ADV)
  Puzzle Extension Shaft (PES)
  Iron Springs (I.S.)
  Streamflow (Q)
  Downstream ('d' subscript)
  Upstream ('u' subscript)

- Contact Information:

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